5.06 Sensitivity of the Soil Moisture Initialization to the Prediction of Cloud and Precipitation in the Coupled Ocean/ Atmosphere Mesoscale Prediction System (COAMPS^{TM})1

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1. Introduction

It is common knowledge that the land-surface soil processes are important to weather prediction. Various studies in the literature have shown great sensitivity of forecast skill to the initial soil moisture. In the past decade, many sophisticated land-surface parameterization with multi-soil layers have been developed to improve the simulation of these processes. Unlike the simple force restore two layer soil model, these new land-surface schemes require many soil parameters to be specified at the initial time. The soil quantities can't be readily obtained by in-situ surface or satellite measurements due to lack of a surface observational network or limited satellite skin level soil information. Two different approaches have been developed by the operational forecast centers in the US and Europe to initialize the soil parameters in the coupled global atmosphere land-surface model (LSM). The first method is to run an off-line land-surface model driven by the observed precipitation, radiation, and meteorology analysis such as the NCEP GDAS and the Air Force Weather Agency (AFWA)'s Agriculture Meteorology (AGRMET) Modeling System. The second method, used by the ECMWF, is based on the local optimum interpolation techniques to relate the 2-m surface temperature and specific humidity increment derived from the surface observations to the soil moisture and temperature increments (Mahfout, 1991).

The scope of this paper is limited to examine applicability of using the global soil analysis on limited area from method one. This is because for military mesoscale operational forecast applications, new forecast areas may need to be set up in a short time and the off-line system usually require a long spin up time (over several years). Therefore, running an off-line simulation of a land-surface model on each mesoscale area is not a very desirable approach. The COAMPS atmospheric model coupled with the NECEP NOAH land-surface model (Chen *et al.*, 1996) is used to investigate the sensitivity of initializing the soil parameters with the AGRMET global analysis. Results from a two-week model simulations during June 2002 and January 2003 over the continental US (CONUS) and Europe areas are described.

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[1]COAMPS^{TM} is a trademark of the Naval Research Laboratory.

2. Model Descriptions and Experimental Design

The COAMPS model is a non-hydrostatic terrain following mesoscale prediction system (Hodur, 1997 and Chen *et al.*, 2003). The model uses an Arakawa C-staggering in horizontal and a terrain following staggered sigma-z vertical coordinate. The COAMPS atmospheric model uses the compressible form of the dynamics. All simulations use the full model physics which include the explicit moist physics, cumulus convective parameterization, radiation, and the planetary boundary layer parameterizations. The surface process can either be computed by the surface energy budget using the force restore method or by the NOAH LSM through a namelist switch. Four soil-layers (10, 40, 100, 200 cm) are used in NOAH LSM.

The off-line ARGMET global soil analysis system has a resolution of approximately 47 km and is running four cycles per day. It uses first guess fields from NOGAPS, surface observations, three-hourly SSMI/rain rate analysis, precipitation analysis based on rain gauge analysis, AFWA SNODEP snow depth analysis, and AFWA CDFSII global cloud analysis. The AGRMET fields used to initialize NOAH LSM are soil temperature, soil moisture, unfrozen soil moisture at four soil levels, canopy moisture content, snow water equivalent, and greenness fraction.

Table 1: Soil initialization sensitivity experiments

Experiments	Cold Start	Warm Start
SLAB	NOGAPS Deep soil temperature from climatology	Previous COAMPS forecast
SLAB with AGR	AGR soil analysis	AGR soil analysis
LSM	USGS 1 km climatology	Previous COAMPS forecast
AGR	AGR soil analysis	AGR soil analysis

Table 1 summarize the four sets of soil initialization experiments that were conducted for the two-weeks periods over CONUS (81x27 km grid resolution) and Europe (81 km grid resolution) areas (Fig. 1). The simulations are 36 hour forecasts with a 12 hour data assimilation cycle. There is no data assimilation for the soil parameters. These parameters are either re-initialized at the data assimilation time with the AGRMET analysis interpolated to the COAMPS grid using the nearest neighbor method or from the previous COAMPS 12 hour forecast.

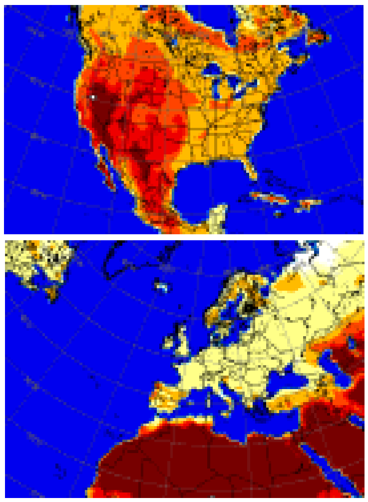

FIg. 1 The model domain set up for the 27 km CONUS (top pannel) and the Europe (81 km) expriments

3. Sensitivity Experiment Results

(a) Europe region

COAMPS is known to have a consistent cold/wet surface and lower troposphere temperature/moisture bias. The magnitude of the temperature biases have seasonal/regional variations around -1 to -3 degree C. The Europe results show that the surface temperature and moisture errors are very sensitive to initial soil condition. When compared the coupled LSM runs initialized with climatology (experiment LSM) and AGRMET (experiment AGR) analysis, in the summer and winter periods, the LSM soil moisture was consistently too dry. The LSM also had a much larger diurnal oscillation. The drier soil allows faster surface heating/cooling during the day/night, Therefore when averaging the day and night scores, the LSM had a warmer/colder surface bias in summer/winter. Because the LSM surface heats up more during the summer day time, it was able to correct the cold PBL biases more in summer. While in winter, the LSM was too cold and dry at the surface.Therefore, the AGR had better PBL biases in winter. In general, over the Europe area, the AGR initialization had much better results than using the climatology for both the SLAB model and the coupled NOAH LSM model.

Europe Nest 1(81 km):
00 UTC June 1 to 00 UTC 11 June 2002

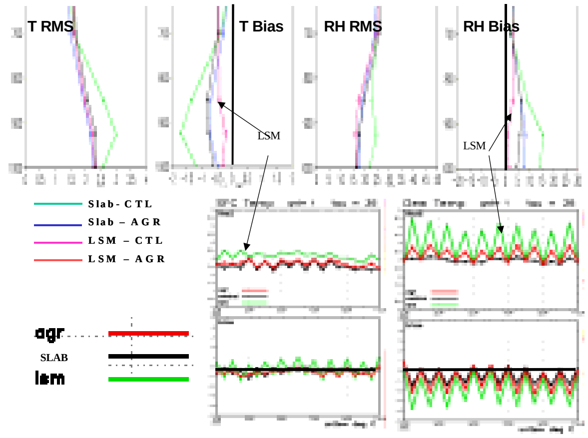

FIg. 2 The model lower troposphere (top pannel) and the surface (bottom pannel) temperature and moisture statistics from the Europe Jun 2002 expriments

Europe Nest 1 (81 km):
00 UTC Jan 1 to 00 UTC 15 Jan 2003

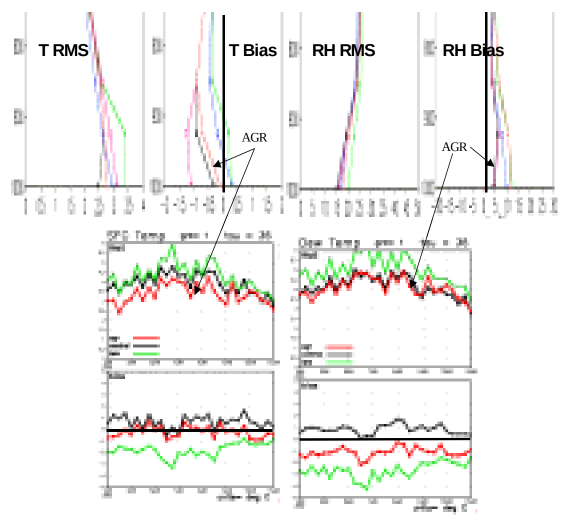

FIg. 3 The model lower troposphere (top pannel) and the surface (bottom pannel) temperature and moisture statistics from the Europe Jan 2003 expriments

(b) CONUS region

The results form the CONUS experiments are similar. At the surface, the runs coupled with the LSM had smaller root-mean-errors and the biases than the SLAB runs in summer and winter. Among the experiments that used the coupled LSM model, in June 2002, the runs using AGR had much better surface temperature and moisture biases than climatology. However, in January 2003, AGR was too dry at the surface. The comparisons of the in-situ 10 cm soil measurements from the Soil Climatology Agriculture Network (SCAN) and the AGR soil analysis showed AGR was slightly moist but too cold during this period (Fig. 6). Because of the colder and wetter soil conditions, less sensible and latent heat fluxes were transferred to the surface resulting in a colder and drier surface biases for the AGR runs. The cloud fraction (as seen by the COAMPS radiation scheme) difference between AGR and climatology initialization during these two weeks also showed the AGR had less low- level cloud over most of the CONUS region (Fig. 7).

CONUS Nest 2 (27 km)
00 UTC Jun 1 to 00 UTC 11 Jun 2002

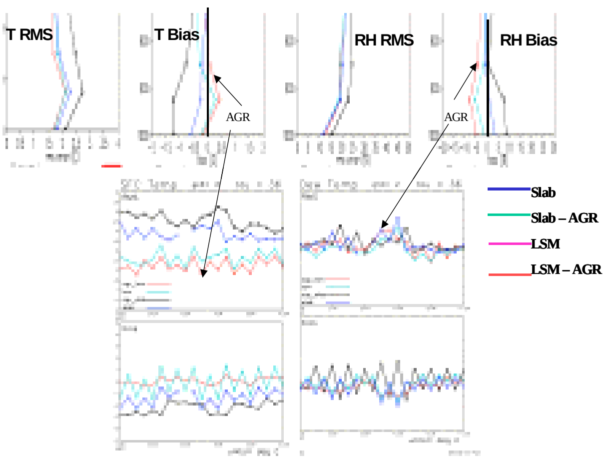

Fig. 4 Same as Fig. 2 excep for the CONUS area

CONUS Nest 2 (27 km)
00 UTC Jan 1 to 00 UTC 15 Jan 2003

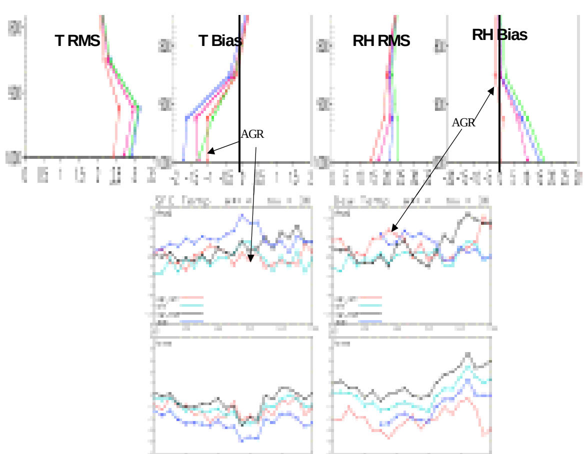

Fig. 5 Same as Fig. 3 excep for the CONUS area

COAMPS^{TM} January 2003 CONUS nest 2 (27 km)

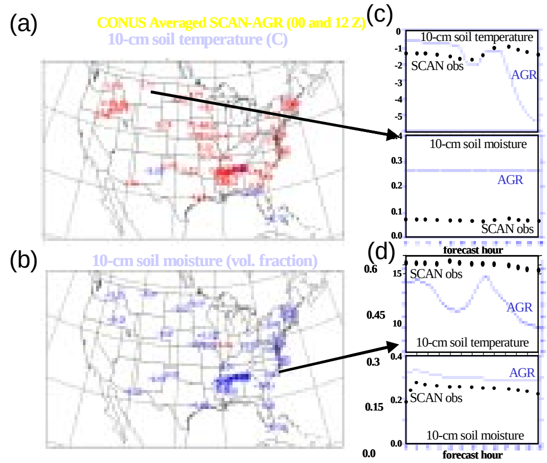

Fig. 6 The averaged 10 cm (a) soil temperature and (b) soil moisture difference between the SCAN stations and the AGRMET analysis (OBS-AGRMET). The comparisons of 00 UTC 1 January 2003 36 hour AGR forecast with the observations at two SCAN station locations (c) near Billings Montana and (d) near Atlanta Georgia are shown on the right pannels.

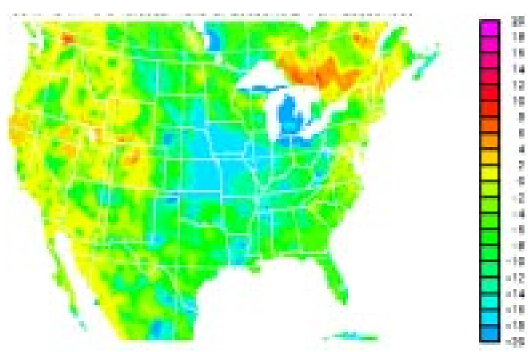

Fig. 7 The averaged low cloud fraction difference (< 1km) between the AGR and LSM (AGR-LSM) during two weeks of January 2003.

In addition to the surface and PBL statistics, the quantitative precipitation forecast (QPF) was also examined. Although the precipitation patterns were similar for individual days for all experiments at the 27 km grid resolution (Fig. 8), the runs coupled with the LSM had better QPF biases in the medium (10 and 15 mm/day) rain thresholds (Fig. 9).

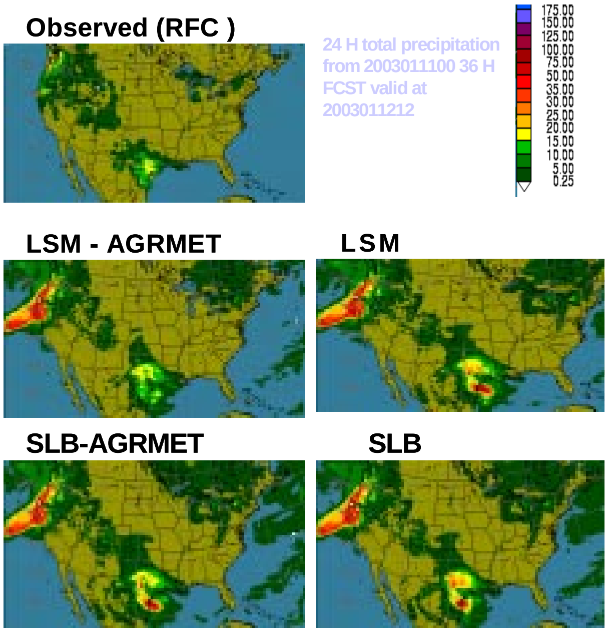

Fig. 7 The observed and model predicted 24 hour total precipitation valiad at January 12, 2003.

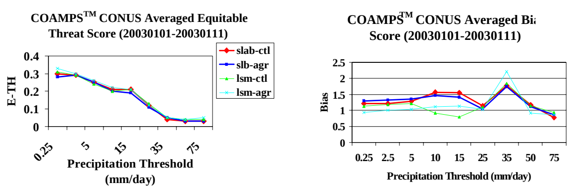

Fig. 8 The averaged model forecast precipitation threat and bias scores during two-weeks of January 2003.

4. Summary

The soil moisture sensitivity tests over the CONUS and EUROPE areas for two-week periods in June and January showed there were improvements using the global AGRMET soil analysis on the mesoscale areas. These preliminary results showed, at 81 and 27 km grid resolutions, using the AGRMET soil analysis improved most of the surface and lower atmosphere temperature and moisture mean and bias errors in three out of the four sensitivity tests. The only exception was the January 2003 CONUS results. The AGRMET soil analysis was found to be slightly moist but too cold compared to the SCAN observations. Different soil initialization were found to have more impact on the low level cloud fractions but had little influence on the 24 hour accumulated precipitation QPF scores. Though the runs coupled with the land surface model using either the climatology or the AGRMET soil analysis did show some improvements on medium rain threshold biases in January 2003.

These preliminary tests have shown encouraging results using a global soil analysis to initiate the LSM parameters in the coupled COAMPS and NOAH LSM model. However our studies did not use any data assimilation on the soil temperature and moisture parameters. This approach has two major short falls. The first one is when using a model grid resolution that is much smaller than the global soil analysis, small scale horizontal soil temperature and moisture gradients created by the model are lost on the next model update cycle. These gradients may be important for the convective cloud initiation (Findell and Eltahir, 2002) and cloud structure on the small scale (Golaz et al, 2001). The second short fall of the approach is we were not able to incorporate special soil observations from satellite measurements or from in-situ surface mesoscale network. Future work will focus on developing the capability of a soil data assimilation using the variational method from the NRL Atmospheric Variational Data Assimilation System (NAVDAS).

5. Reference

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